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OUR AQUATIC BIOLOGICAL RESOURCES

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Introduction

Civilization is dependent upon water—the sea, rivers, lakes, ponds, streams, and marshes touch every aspect of human life. Much attention has been given to water supply for drinking and domestic purposes, to water power, and to the carrying away of filth and waste from the innumerable operations that are an essential part of modern civilized life. These things are so important and so involved in traditional and vested property rights and the convenience and profits of modern industry that an entire series of important natural aquatic resources has been crowded aside and almost forgotten. These are:

(a) Animal resources: fish, turtles, frogs, mussels, shellfish, and aquatic birds and mammals;

(b) Plant resources: aquatic vegetation, stream-skirting shrubs and trees, providing feeding and nesting places for important animals;

(c) Museum resources: preserves of aquatic and riparian faunas for future scientific investigation and for possible practical uses;

(d) Recreational resources: bathing, rowing, camping, angling, shooting;

(e) Esthetic resources.

The preservation of these resources often conflicts with those more generally recognized. Much has been written on the subject of the balance in nature, but little attention has been given to it even in quasi-biological circles. The tendency has been rather to "improve" and "develop" our water resources, including stream and lake margins, as well as roadsides and right-of-ways,[1] without reference to the requirements of animals and plants originally dependent upon natural conditions and of recognized value to mankind. Furthermore, there is reason to believe that the value of the biological products of our coastal and inland waters and water margins has been underestimated.

First, the monetary values assigned such products in census reports have, for some items, been too small. The occasional character of the investigation has been productive of inaccuracy. Only those products which have actually been shipped through market channels have been counted; the local and private supplies often, if not usually, have been omitted.

In 1908 the fisheries products of the United States, exclusive of whales but including mollusks (oysters, etc.) and sponges, were valued at upward of $53,000,000. Of this sum about $7,000,000 is to be credited to inland waters. Frogs, turtles, terrapin, alligators, and fur-bearing animals were valued at $500,000. The value of frogs for the entire United States (1908) was $42,000, while $15,000 were reported from Oneida Lake (New York) alone, which covers only 80 square miles (1916). Turtles and terrapin are given a value of $122,000, while the Louisiana Conservation Commission reports $100,000 to $110,000 a year for Louisiana alone (1917). There may have been increased catch, increased prices, but not sufficient to account for the differences indicated. In general the state census bureaus, which operate continuously, make larger estimates than the federal bureau.

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[1] W. L. McAtee: Attracting Birds to Public and Semipublic Reservations. *U. S. Dept. of Agric. Bull. No. 715*, 1918.

Second, the real value of aquatic resources has been depreciated by erroneous comparisons. As a rule only fishes, which make up the smaller part of the total, get consideration. Their value is small after pollution and overcatch have reduced their numbers. It has been argued that the fisheries of one of the most productive rivers are not worth as much as the products of the smallest industry that throws waste matter into it. This argument carries much weight with legislatures. It is, however, faulty and untenable. First of all, the values used for fish are their value to the fisherman. The Alaska salmon-canning industry shows[2] that the value of the fish to the fishermen is about one-third the value of the canned product to the canneries. Fish and other aquatic products should be compared with *raw materials* and not with the products of factories on which much labor has been expended.

Value of Biological Resources

FRESH-WATER FISHES AND MUSSELS

The most prized fresh-water fishes and mollusks are dependent upon clean bottoms, abundant vegetation, and a good flow of water in dry seasons —conditions which characterized our streams in primeval times.[3] Clearing of timber has modified stream flow, stream margin shade, etc., detrimentally. Household and industrial effluent dilution has modified the character of the water and covered the bottoms with filth, to the destruction or injury of fishes and their associates.[4]

In the settlement and early development of our country, fishes were very important. There were shad, salmon, trout, bass, alewives, eels, and many other kinds. They furnished a plentiful supply of healthful food, easily attainable, until the forests could be hewn down and crops raised.[5] Shad was the most important variety and was abundant in all Atlantic coast rivers. In Pennsylvania the country folk came from fifty miles away to get their winter supply, camping along the rivers and bringing in payment whatever they had of a marketable nature.[6] Now shad, together with salmon, is greatly reduced in Atlantic coast streams. In the Illinois River years ago the buffalo fish afforded the chief marketable species. In recent years it has constituted less than eight per cent of the total fish catch.[7] Buffalo-fish eggs are unusually sensitive to various unfavorable influences. The whitefish of the Great Lakes, which served as bread, meat, and vegetable to the early explorers and settlers, was once abundant.[8]

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[2] B. W. Evermann: Alaska Fisheries and Fur Industries in 1913, *U. S. Commission of Fish and Fisheries, Report for 1913*, Appendix II, pp. 1-139.

[3] V. E. Shelford: Animal Communities in Temperate America, *Bull. Geogr. Soc. of Chicago No. 5*. Chicago, 1913.

[4] V. E. Shelford: Fortunes in Wastes and Fortunes in Fish, *Scientific Monthly*, Vol. 9, 1919, pp. 97-124; *idem*: Ways and Means of Measuring the Dangers of Pollution to Fisheries, *Bull. Illinois State Nat. Hist., Survey*, Vol. 13 (2), 1918, pp. 25-42.

Ruthless catching has been followed by sewage, and sewage by industrial wastes.[9] Lead works, zinc works, tanneries, paper mills, and gas plants[10] turn valuable and extremely poisonous substances into the streams and lakes. In Europe nearly all industrial wastes have been converted into something useful.[11] In America manufacturers have not cared to spend time and energy in dealing with the matter.

The extent of the damage done by pollution at the present time may be judged by the fact that 60 per cent of the suggestions concerning the improvement of fisheries and the increase of the product during the war dealt with pollution. The condition of streams in America is worse than in Europe mainly because Europeans have been giving attention to the matter while we have neglected it.[12]

Fresh-water mussels for making pearl buttons constitute an important resource. It is one which is decreasing, however, from overcatch and pollution which destroys the fish upon which the mussels depend.[13] In 1908 the value of the mussels taken from the Mississippi and its tributaries was estimated at $686,000.[14]

MARINE FISHERIES

The marine fisheries of the United States in 1908 had a value of about $45,000,000. The sea and its shallows are highly productive of human food, including fish, shellfish, crustaceans, trepang, etc.;[15] it has been said that four square feet of ocean will support a human life.[16] The cultivated mussel beds of Conway produce 8,600 pounds of flesh per acre, while the productivity of land in beef is about one-ninth of this. The dry mussel flesh is about six-tenths of the dry organic matter produced in grain from the same area of land. Investigation of the possibilities of food culture of the sea should be greatly extended; our knowledge barely exceeds that of the savage. There are many marine animals not ordinarily eaten which are excellent food.

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[5] Harrison Wright: On the Early Shad Fisheries of the North Branch of the Susquehanna River, *U. S. Commission of Fish and Fisheries, Report for 1881*, pp. 619-642.

[6] W. E. Meehan: The Battle of the Fishes, *Canadian Fisherman*, Montreal, Vol. 4, 1917, pp. 275-277.

[7] This information was supplied by Mr. R. E. Richardson.

[8] F. N. Clark: A Plan for Promoting the Whitefish Production of the Great Lakes, *Bull. U. S. Bur. of Fisheries*, Vol. 28, 1908, Part I, pp. 635-642.

[9] M. C. Marsh: The Effect of Some Industrial Wastes on Fishes, *U. S. Geol. Survey Water-Supply Paper 192*, pp. 337-348.

[10] V. E. Shelford: An Experimental Study of the Effects of Gas Waste Upon Fishes, with Especial Reference to Stream Pollution, *Bull. Illinois State Laboratory of Nat. Hist.*, Vol. 11, pp. 382-412, Urbana, 1917.

[11] Theodor Koller: The Utilization of Waste Products (translated from second revised German edition), London, 1915.

[12] H. B. Ward: The Elimination of Stream Pollution in New York State, *Trans. Amer. Fisheries Soc.*, Vol. 48, 1919, pp. 3-25.

[13] R. E. Coker: The Protection of Fresh-Water Mussels, *Bur. of Fisheries Doc. 793*, 1914.

[14] The Fisheries of the United States in 1908, U. S. Bureau of the Census, Washington, D. C., 1911.

The supply of lobsters, cod, and many other fish decreased markedly soon after the beginning of the industrial period in New England. This was in part due to overcatch and to the damming of rivers, as stated before, but pollution of the seas was no doubt an important factor also. It is probable that pollution of the sea affected runs of herring and had an important influence on the decline of the Baltic cities in the fourteenth century and on the rise of Amsterdam.[17] In fact, marine animals of economic importance require pure water, clean bottoms, and natural vegetation. Practically all changes accompanying settlement are detrimental to the best food species. The sea is large, but marine animals are much more sensitive than fresh-water animals.

FISHWAYS

For the proper protection of fishes and mussels fishways, fish elevators, etc., are needed in connection with river improvements. In the North Branch of the Susquehanna, in Pennsylvania, "the shad industry was wholly abolished by the erection of dams to feed canals (early in the last century), and thousands of dollars of capital invested in the business was instantly swept out of existence."[18] The canals have been quite generally abandoned in recent years. Experience with such improvements raises the question of their permanent value.

The best type of fishway[19] is the stream itself, and the aim should be to reproduce stream conditions so far as current is concerned. A cost equaling half the cost of the dam is not too much to expend to accomplish the desired result. Fishways have usually been added to completed dams as a sort of cheap adjunct after the fishes have already been depleted from several years of failure to migrate. The importance of fishways is well illustrated by a statement by Coker[20] relative to the Mississippi dam at Keokuk, Iowa, which runs as follows: In their early stages of development pearl-button mussels are parasitic on particular species of fish. Conditions which affect the movements of the river herring, which is the host of the niggerhead mussel, and the catfish, which is the host of the pimpleback mussel, may vitally affect the welfare of these important mussels. If the river herring is checked by the interposition of a dam, so that comparatively few find the way into the upper river, two results will follow: (1) the fish will become a rare species in the upper river, and (2) the mussels will become extinct in that portion of the Mississippi River lying above Keokuk —that is in practically the entire mussel-producing portion.

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[15] James Johnstone: Conditions of Life in the Sea, Cambridge, 1908; see especially pp. 178-205.

[16] I. A. Field: The Ultimate Sources of Marine Food, *Trans. Amer. Fisheries Soc.*, New York, Vol. 45, 1916, pp. 177-190.

[17] John Yeats: The Growth and Vicissitudes of Commerce in All Ages, London, 1887.

[18] Work cited in footnote 5.

C. G. Atkins: On Fish-ways, *U. S. Commission of Fish and Fisheries, Report for 1872-73*, Part II, pp. 591-616.

[19] Hector Von Bayer: Fishways, *Bull. U. S. Bur. of Fisheries*, Vol. 28, 1908, Part II, pp. 1043-1057.

The usual "custom" in such matters will probably be followed here. There will be no fishway until in time we discover that damage has been done, and then the fisheries will not be worth the making of one. In 1908 the fisheries of the Mississippi and its tributaries in Iowa, Minnesota, northern Illinois, and Wisconsin had a total value of more than $500,000.[21] The value of mussels and pearls alone was almost $100,000. If an annual $600,000 fisheries project is endangered, why could not such a sum reasonably be expended for a suitable fishway?

It is doubtful if any salmon stream should ever be dammed without a fishway costing the full annual value of the fish, if necessary. Salmon were exterminated in the Connecticut River by a dam built in 1798. This also shut out shad and alewives. The value of the shad fisheries of the Delaware about this time was $200,000 per year. With salmon and alewives included, the Connecticut fisheries should have more than double this. An expense of ten per cent of the annual value of the fisheries could have constructed a fishway quite adequate for all the fish. The very large one in the Susquehanna built in 1873 cost only $11,053. It probably paid to build this dam in 1798, but whom did it pay? Certainly not starving Europe in 1918.

In general river engineers have taken little or no notice of either fishes or fishways. In 1872 Professor Baird[22] said of the cod fisheries: "Formerly the waters abounded in this fish.... The tidal streams were choked up with alewives, shad, and salmon. The erection of impassable dams across the streams, by preventing the ascent to their spawning grounds, produced almost the extermination of their numbers. The reduction in the cod and other fishes so as to become practically a failure is due to the decrease off our coast in the quantity of alewives, and secondarily of shad and salmon, more than any other cause."

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[20] R. E. Coker: Water-Power Development in Relation to Fishes and Mussels of the Mississippi, *U. S. Commission of Fish and Fisheries, Report for 1913*, Appendix VIII, pp. 1-8.

[21] Work cited in footnote 14.

[22] S. F. Baird: Conclusions as to Decrease of Cod-Fisheries on the New England Coast, *U. S. Commission of Fish and Fisheries, Report for 1872-73*, Part II, pp. xi-xiv.

FROGS, TURTLES, AND CRUSTACEANS

The swamps and marshes near all the large cities produce quantities of frogs, but the numbers and values are unknown. The legs are used for food. This constitutes the frog's chief value, but many are used in scientific laboratories. Fifteen thousand dollars' worth are secured annually from the margins of Oneida Lake, N. Y.[23] It is safe to say that this value in frogs is produced on 1,500 acres of shore and shallow water, which means a yield of $10 per acre without cultivation; and this is only one of many products and values for the same area.

Frogs, like all other animals, must have proper conditions for successful reproduction and growth. The bullfrog requires cool, deep waters and margin shrubbery under which to rest out of water. Other smaller species have definite shore and breeding-water requirements.

Turtles live about lake and river margins and deposit their eggs on land, some in dry sand, some in moist mud, some in decaying vegetation. They are very sensitive to disturbances of their breeding grounds and accordingly decrease as the country is improved. Crayfishes are, as a rule, eaten only by our foreign population but have a distinct value on the market.

BIRDS

North America possesses about two hundred species of game birds which are associated with watercourses, lakes, swamps, and the seashore.[24] This number includes 74 species of edible web-footed fowl. Sixteen of these have been shown to feed upon wild rice, wild celery, and pond weeds.[25] These three plants supply an average of 25 per cent of their food, more than half of which consists of pond weeds which grow well in waters not too badly polluted. These birds are all closely dependent upon water for breeding.

Ducks eat quantities of grasshoppers, locusts, cutworms, and marsh caterpillars. The rails and coots have similar habits and relations. All are useful to the farmer. There are some sixty species of long-legged slender-billed birds, the so-called shore birds.[26] These devour quantities of mosquitoes, horseflies, etc., both adult and larval. Nearly all these birds are very fond of grasshoppers, and many feed on weevils, wireworms, leaf beetles, and other pests of the field. Many birds associated with water are useful to agriculture, and their destruction ultimately results in heavy losses to the farmer through the increase of insect and other pests. These are also the birds hunted for food and for sport.

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[23] Charles C. Adams and T. L. Hankinson: Notes on Oneida Lake Fish and Fisheries, *Trans. Amer. Fisheries Soc.*, Vol. 45, 1916, pp. 154-169.

[24] E. H. Forbush: History of the Game Birds, Wild-Fowl, and Shore Birds of Massachusetts and Adjacent States, Mass. State Board of Agric., Boston, 1912.

[25] W. L. McAtee: Five Important Wild-Duck Foods, *U. S. Dept. of Agric. Bull. No. 58*, 1914; *idem:* Eleven Important Wild-Duck Foods, *U. S. Dept. of Agric. Bull. No. 205*, 1915.

[26] W. L. McAtee: Our Vanishing Shorebirds, *U. S. Bur. of Biol. Survey Circular No. 79*, 1911; also work cited in footnote 14.

MAMMALS

The small fur-bearing mammals closely associated with watercourses—beavers, muskrats,[27] skunks,[28] and minks—are valuable for their fur. The skunk is counted as a useful animal and is fond of stream-margin thickets. Its bad reputation for taking poultry is unfounded, based largely on rare instances and on the fact that the European polecat, from which it gets its name in some localities, is a serious poultry pest. These mammals decrease or disappear with the destruction of shallow-water vegetation and shore shrubbery.

AQUATIC PLANTS

Aquatic plants are not without value. In aboriginal times a number of rushes of different sorts were used for making coarse mats and other suitable articles. In recent years the leaves of the narrow-leaved cat-tail have been employed in paper making and in cooperage.[29] Water plants, notably wild rice, supplied food to the American Indians. Flour of good quality has recently been made from the cat-tail.[30] Hedrick[31] has advocated multiplying the variety of crops. "In China and Japan the corms, or tubers, of a species of *Sagittaria* (arrowhead) are commonly sold for food. There are several American species which under the name arrowhead, swan potato, and swamp potato have given welcome sustenance to pioneers. Our native lotus, a species of *Nelumbo,* was much prized by the aborigines, seeds, roots, and stalks being eaten. *Sagittaria* and *Nelumbo* furnish starting points for valuable food plants for countless numbers of acres of water-covered marshes." Research on the cultivation of these should have been started long ago.

Special Localities

Semi-aquatic situations, such as water margins with their vegetation and swamps and marshes, constitute some of our most valuable and too-little-considered resources. They are linked with all truly aquatic resources in ways suggested above so as to be inseparable from them.

WATER MARGINS

The statistics collected in Illinois show that two-thirds[32] of all the birds

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[27] D. E. Lantz: The Muskrat, *U. S. Dept. of Agric. Farmers' Bull. 396,* 1910.

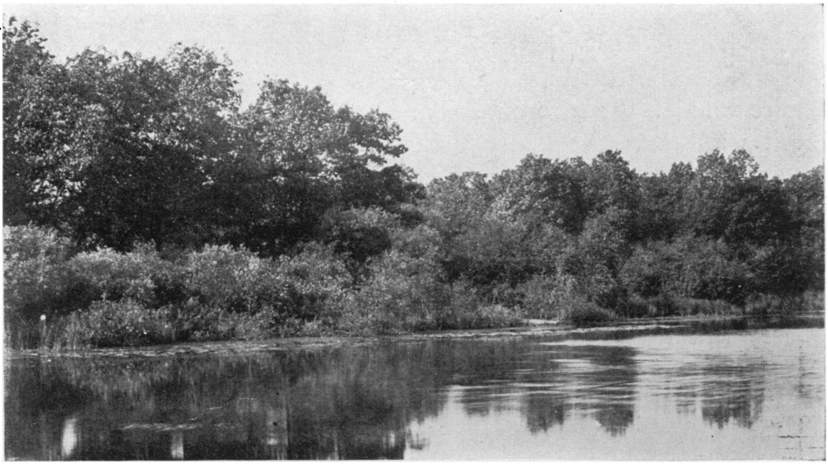
[28] *Idem:* Economic Value of North American Skunks, *U. S. Dept. of Agric. Farmers' Bull. 587,* 1914.

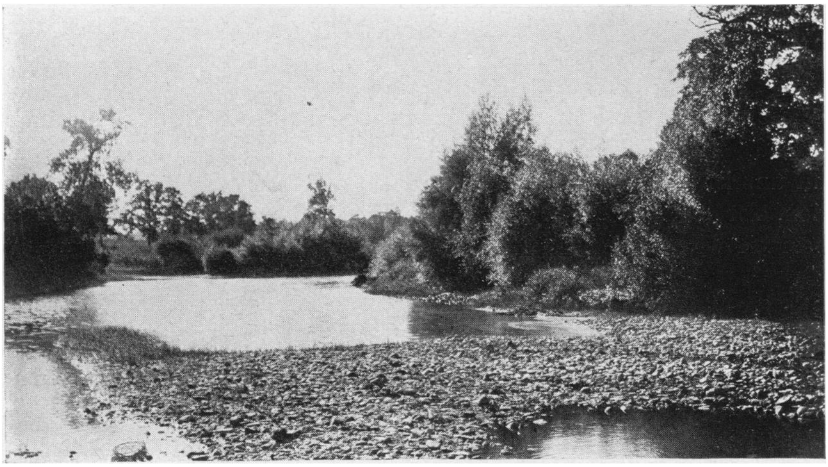
[29] J. G. Needham and J. T. Lloyd: The Life of Inland Waters: An Elementary Text Book of Fresh-Water Biology for American Students, Ithaca, N. Y., 1916, p. 381.

[30] P. W. Claassen: A Possible New Source of Food Supply, *Scientific Monthly,* Vol. 9, 1919, pp. 179-185.

[31] U. P. Hedrick: Multiplicity of Crops as a Means of Increasing the Future Food Supply, *Science,* No. 1035, Vol. 40, 1914, pp. 611-620.

[32] Frank Smith: The Relation of Our Shrubs and Trees to Our Wild Birds, *Illinois Arbor and Bird Days Circular No. 83,* pp. 8-17, Supt. of Public Instruction, Springfield, Ill., 1915.





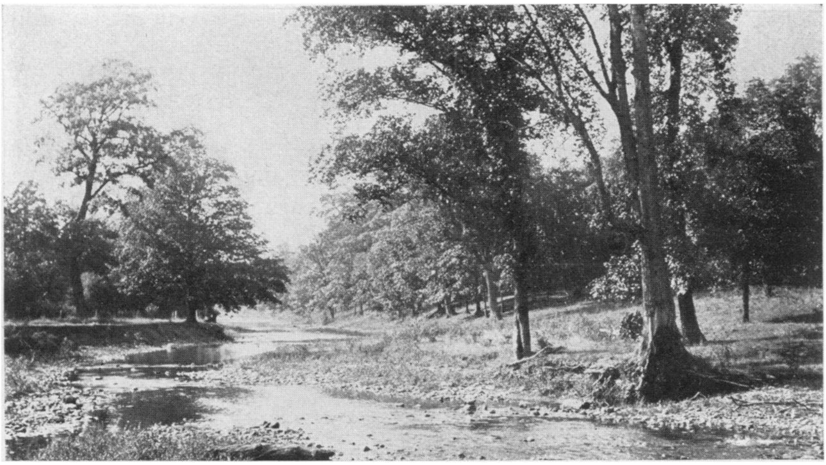


FIG. 1—A sluggish Indiana stream with its margin in a primeval state. Note four zones of vegetation—water lilies, low shrubs, high shrubs, and trees.

FIG. 2—A small Illinois stream with its margin in the original condition. Note a growth of shrubs with a few trees behind them.

FIG. 3—The same stream shown in Fig. 2, about a mile from the point there shown, on the farm of a different owner. A few trees are left, but all shrubs which make important bird-nesting sites have been destroyed by cutting or overgrazing.

which are valuable for eating insects and which, for the most part, are not included with the shore and aquatic birds, are in some way dependent upon shrubbery such as grows on the margins of watercourses (Figs. 1 and 2) and such as might be cultivated along roadsides.[33] The bobwhite, for example, breeds about thickets and is of especial value to the farmer. It has been predicted that in the Middle West, where farmers are inclined to clear away all the bushes (Fig. 3), many of the species dependent upon shrubbery will disappear. The tendency to destroy the thickets, especially on the stream margins, causes an obvious decrease of birds. A good skirting of trees along streams is also conducive to the presence of fish, because many food fishes prefer shade. Shade also greatly increases recreation value. As a rule, the lowest land along streams is not useful for anything but for growing trees and shrubs.

Swamps

Those who advocate swamp drainage appear to consider it as an unqualified good. On the other hand, some regard the drainage of certain swamps as an unmitigated evil. The preservation of the entire Everglades swamp region, for example, might seem absurd; but it is not so absurd as it appears if we give full consideration to the value of our North American birds.

Our Southern swamps lie in the direct migration route of many species of birds that are used as food or that destroy crop pests farther north.[34] This is so important that through gifts and state acquisition Louisiana has set aside areas of swampy land along the southern coast to serve as way stations for migrating birds and as breeding places for the native species. The marshes and watercourses of Louisiana yield upward of $700,000 a year in food, furs, etc. No swamp in the Gulf States or Georgia should be drained without full consideration of these losses. Experiment stations should be established, and at these stations studies should be conducted of the means of increasing the productivity of marshes.

Upland marshes also have values similar to those of the lowland marshes and coastal swamps, with an additional and important function. With the clearing off of timber and the draining of such swamps the streams are subject to greater floods and to extreme low water. At extreme low water a very small amount of pollution overtaxes the self-purification mechanisms, with results almost as disastrous to fishes and similar animals as if the low water occurred throughout the year.

There has been much discussion of the necessity of building dams from which water could be slowly released in dry seasons to maintain flow. Why then destroy the upland marshes which serve as reservoirs, or as great sponges holding water and letting it out gradually? Needham and Lloyd[35] advocate lowering parts of these below permanent water level and putting the soil thus removed on equal areas. The dry land could be used for agriculture, and the ponds for water culture. Though the science of aquiculture is as yet in its infancy, it appears that fresh water may be made as productive as land.

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[33] W. L. McAtee, work cited in footnote 1.

[34] M. L. Alexander: Conservation Laws of Louisiana...., State Conservation Commission, New Orleans, 1916.

A part of any large swamp such as the Okefinokee Swamp, or any other natural area, is as valuable as the most expensive American museum, one which requires say an endowment of $10,000,000 and an annual expense of $500,000. Such swamps are really museums of living things, the value of which at any time may become infinitely great in the solution of important scientific problems which involve living animals. Each year animals and plants find new uses and new values; a century ago no one would have thought white rats, guinea pigs, and common mice worth saving. If the question of sacrificing all these for a little additional land to cultivate had been raised it would have received but one answer. Yet by far the greater part of our laws of immunity from disease and of heredity—especially heredity of cancer—have been or are still being worked out on these animals. To quote a recent writer on water culture: "We urge that water areas, adequate to our future needs for study and experiment, be set apart and forever kept free from the depredations of the exploiter and of the engineer."

Brackish-water swamps serve as important breeding places for wild fowl. The low wet areas along the New Jersey coast have been notorious for the mosquito pest. The increase of mosquitoes in recent years has been attributed to the decrease of insect-eating shore birds and waterfowl. To perfect the control of the mosquitoes, systems of ditches have been provided by which small fishes, the killifishes, are enabled to get at and devour the larvae and pupae. During the war, in 1917-1918, the munition works discharged a mixture of sulphuric and nitric acids into these waters which repelled the killifishes and locally neutralized the effects of the ditching work.

Recreational Values

In addition to their value as producers of aquatic products used for food, buttons, clothing, etc., streams and bodies of water have a recreational value. The recreation values may be roughly divided into two classes, (a) sportsman's and (b) park. The value of the former may be ascertained by estimating the value of all clubhouses, cottages, boats, launches, etc., which are directly dependent upon the river or lake.[36] The value of these is the capitalization, on which interest may be computed. The interest, salaries of caretakers, and value to local merchants constitute the annual value. These activities tend to disappear from badly polluted streams. Park value is best ascertained from the statistics of cities.[37] The larger American cities (e. g. Chicago) spend annually from $2.00 to $4.00 per capita on parks (exclusive of lighting and including interest on investment) and outdoor swimming pools. Clean lakes and streams also have an esthetic value on which no price can easily be set. The question of whether or not streams shall receive untreated wastes beyond a very limited amount, and whether wastes shall be treated or not, is largely an ethical question and is best settled as such. The nation has preserved certain areas as national parks, national monuments, national forests, etc., for the use of the nation as a whole. The states have reserved some similar areas. The humblest citizen has a right to the recreation values of some of the bodies of water near his home, and his children should be able to wade in a near-by stream and pick up stones without danger to health. The day is past, even in America, when these general interests can be sacrificed for the profit of a small group of citizens.

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[35] Work cited in footnote 29.

[36] G. E. McCurdy: Report of Survey and Proposed Improvement of the Fox River, State of Illinois Rivers and Lakes Commission, Chicago, [1915].

C. D. Hill: The Sewage Disposal Problem in Chicago, *Amer. Journ. of Public Health*. Boston, Vol. 8, 1918, pp. 833-837.

Water Fertilization, Self-Purification, and Pollution

It is a fact that a certain amount of purely household sewage added to water increases nitrogen and hence acts as a fertilizer, producing more food for fish and other aquatic animals. Certain European towns run their sewage into ponds where the yield of carp is increased through the increase of fish food.

In America there is no such thing as purely household sewage; even in the smallest town the garage runs oil and gasoline into the sewers, the creamery adds milk wastes, or the gas plant adds quantities of deadly poison, until there is really no certainty that the process of breaking down the organic matter of the household sewage present into nitrogen available for fish food will go on. In addition, washings from roads surfaced with various tars and oils complicate matters and kill the fish.[38] This subject has received careful attention in England.

How much sewage can be used advantageously as fertilizer? The amount that can be used for carp is detrimental to most aquatic resources, because carp are more resistant than almost any American food fish. When is a stream self-purified? The sanitary chemist and bacteriologist have criteria, but they fail for important aquatic organisms. A large number of questions demand investigation. Tests of the toxicity of sewage and industrial wastes and other poisons introduced into the water must be made, as a basis for rendering them harmless.[39] The question, often asked, as to whether or not a given substance will injure fishes,[40] in general cannot be answered. First of all, the resistance of different species and of different stages of the same species, differs as much as fifty-fold for the same poison.

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[37] General Statistics of Cities: 1916, U. S. Bureau of the Census, Washington, D. C., 1917.

[38] W. J. A. Butterfield: Relation Between Modern Road Surfacings and Fish Life, Inst. of Municipal and County Engineers, London, 1912.

Conditions in streams and other bodies of water vary. The summer low-water conditions are dangerous because of little flow, of concentration of polluting substances, and of high temperature, which increases toxicity; the winter low-water conditions are dangerous because of slow flow and because of the presence of ice, which prevents aëration.

There are various methods, new and old, of treating sewage. It is true that European plants for the recovery of sewage materials by the older processes have failed to pay profits. It is possible that methods, old or new, pay only when the damages which result from pollution are taken into account. The damages must include a value on all resources represented by a stream or other body of water. Sewage contains much nitrogen needed to maintain soil fertility. It is recovered and put into form suitable to return to the land with doubtful success at the present time,[41] but that is largely because of the lack of adequate effort.

The pollution of the sea is quite extensive near our populous areas. The most widely known of its several effects is the contamination of shellfish beds and bathing beaches with typhoid. To prevent this Winslow and Mohlmann[42] have proposed the sterilization of the New Haven sewage, thus putting a value on sterile media for bathing beaches and oyster beds. The Miles acid, which they favor, gives an effluent less dangerous to fisheries than raw sewage, as a slight treatment by some aërating process removes the SO_2 used and leaves intact all the benefits from the standpoint of public health.

Danger to public health is recognized by the International Joint Commission,[43] who gave the opinion that no untreated sewage should be introduced into the boundary waters between the United States and Canada. Here stands the British Empire ready to defend its humblest citizen! The benefit of such a policy in our national waters would accrue to the health of the downstream neighbors of a community that treats its sewage.

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[39] V. E. Shelford: Work cited in footnote 10; *idem:* Second work cited in footnote 4.

M. M. Wells: The Reactions and Resistance of Fishes to Carbon Dioxide and Carbon Monoxide, *Bull. Illinois State Laboratory of Nat. Hist.*, Vol. 9, pp. 557-571, Urbana, 1918.

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Co-operative Research and Permanent Basis of Production

From lack of knowledge, or through carelessness, we have continually recurring destruction of various natural agencies that work in part toward the good of mankind. Study of these has been made, but our private organizations and our individual efforts are scattered. The work of our government bureaus has often fallen into ruts which have crushed out the individual initiative of the investigators. Often all effort has been directed toward the establishment of the pet hypotheses of those in charge. In our government organizations these investigating bureaus are usually separate, often competitive, usually not based on the logical requirements of the problems to be studied, and frequently guilty of undue generalization. Organization should be such that a complete force of investigators can be put to work on a problem. What should be done with this or that swamp? It is not a problem for engineers alone. First of all there should be a careful study of all its products—wood, lumber, fish, game, furs, etc., and their value. Foresters, zoölogists, ornithologists, chemists, engineers, and ecologists (who deal with the fine adjustments of organisms to one another and to conditions) should constitute a co-operative organization.

It is well to picture the items which enter into the draining or pollution of a shallow lake or bayou. Assume that the body of water lies in a populous region, contains 40 square miles of water and swamp, and is connected with a stream used for water power, for recreation, for waste dilution, and for navigation. On its shores is a small city of 10,000 inhabitants. What is its value in a primeval state?

ESTIMATED VALUE, BEFORE DRAINING, OF THE RESOURCES OF AN IMAGINARY LAKE NEAR A SMALL CITY

Food and Clothing		
Frogs and crayfishes shipped	$15,000	
Fishes and turtles shipped	12,200	
Fish caught by anglers	300	
Game birds shot	300	
Plant products	200	
Mammals—skins and food	500	
Value of shore birds to crops	30,000	
Total	——	$58,500
Recreation		
Park value to a town of 10,000 (based on expenditure of cities)	$30,000	
Sportsman's value (interest on $100,000 invested in boats and cottages)	5,000	
Net profits to community from recreation visitors	10,000	
Total	——	45,000
Water Conservation		
Water-storage value as insurance against floods and extreme low water, as a protection against loss to fisheries, water power, recreation, and navigation downstream	$30,000	30,000
		$133,500

A study of the literature of the subjects concerned, cited on the preceding pages, will show that the figures assigned are not unreasonable. Ought a community of 10,000 to destroy the food and recreation values ($103,500) of the lake to the extent of 40 to 80 per cent in order to save a $30,000 annual expense for treating sewage and industrial wastes? The answer is obviously No. Should three-fourths of the 40 square miles be converted into farms at an expense for ditching and diking of $1,000,000, including title, and the land sold at a profit of $1,000,000? The land might produce $500,000 worth of food each year, with the complete destruction of $133,000 value, leaving $367,000 to cover increased cost of labor in cultivation and interest on investment, but perhaps nothing more. However, the increase in food production is highly desirable. The dangers to the downstream inhabitants from floods and drought, which increase as population increases, constitute not merely a monetary loss, but the maintenance of stream flow is a moral obligation growing with the population.

Then why does such drainage take place? It is primarily because certain rights to land based on English common law have become established, and the interest of the owners lies in profits and dividends rather than in a consideration of the general good. The interest of sanitary engineers, users of water power, navigators, sportsmen, fishermen, in fact all concerned in maintaining a steady flowing stream (both floods and extreme low water are dangerous) points to the development of aquiculture in lakes and marshes connected with important streams. Before much progress can be made, both research and legislation are necessary. Our laws relative to riparian rights, like those of England which caused the destruction of the salmon in the Mersey, do not make possible the application of the best measures for the general good to marshes and streams and their margins. The laws should be improved, and campaigns of education should be inaugurated.

Above all, there is need of putting existing aquatic resources on a permanent basis. There has been too much fish "mining," mussel "mining," i. e. too much of the tendency to take all and go to the next place or the next product, and not enough "farming" of these resources. Why, with all our immense rivers, should we import mussels from China? Is it not better to work out a basis for a permanent supply from our own waters? Here research is necessary; as yet we know little or nothing about what portion of the individuals of any species can be safely removed each year and leave a permanent supply under the best conditions we can devise.